On the use of Sentinel-1 (IW/EW and WM modes) for iceberg detection applied to sail racing around the world

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J. Viard, N. Longépé, P. Vincent, R. Husson, G. Hajduch, V. Kerbaol – CLS

J. Tournadre – IFREMER
Vendée Globe
The only non-stop solo round the world yacht race without assistance

Period (every 4 years)
From November to January/March

Participants
29 skippers w. yachts from different generations

Length
~22 000 nautical miles
1/3 in areas potentially populated by icebergs

Antarctic Exclusion Zone (AEZ)
- To prevent siling too far South to avoid icebergs drifting on starboard
- AEZ will be regularly updated during the Race
CLS’s role in Vendée Globe

- Delivery of 2 historical services
  - Since 2004: a 24/7 *location and tracking service* of the yachts
    - Using MAR YI iridium beacon to establish the ranking and to provide assistance to sailors
    - Using MAR VR in case of capsizing
  - Since 2008: An operational *iceberg detection service*
    - Using Altimetry and SAR as primary source of observations
    - Complemented with a drifting model for Icebergs
EO missions used: From 2008 to 2012

**VG 2008**
- Radar imagery: ENVISAT
- 1 SAR satellite

**VG 2012**
- Radar imagery: Radarsat-2
- 1 SAR satellite

**VG 2016**
- Radar imagery: Radarsat-2, Sentinel-1A, Sentinel-1B
- 3 SAR satellites
- Incl. Wave Mode
- + MODIS

**Altimetry**
- 2 satellites
- 4 satellites
Iceberg detection

- Two complementary techniques based on Radar EO satellites
  
  1. Radar Imagery (SAR):
     - Wide swath products: S1 EW/IW, RS2 SCW/SCN, up to 500x500km.
       - Acquired and processed in NRT at VIGISAT ground station
     - Wave Mode imagette: synoptic situation at global scale
  
  2. Radar Altimetry:
     - synoptic situation at global scale

  Minimum size of iceberg detected 100m depending of the satellite instrument capability resolution

- Analysis, Validation and Interpretation using Meteocean data and ancillary data sources:
  - In situ observations
  - Sea temperature, wind, current
  - Suspicious satellite iceberg detections compared to SAT-AIS (confidence index of the detection)
Iceberg detection service

- **SAR Observation satellite**
- **Altimetry Observation satellite**
- **AIS**
- **Meteocean data**
  - Current
  - Wind
  - Temperature
- **Ship location**
- **Operationa l expertise**
- **SAR & Alti expertise**
- **CLS Team**
  - **24/7**
- **Iceberg expertise**
- **Shared expertise**
- **Google Bulletins 11:00 UTC**
- **Text & Images Bulletins**
- **FTP**
- **Race Management**
Detection strategy

• **Phase 1: before Start**
  – Altimetry + Wave Mode SAR acquisitions
  ➔ To obtain a general situation in the South & to setup a 1st version of the Antarctic Exclusion Zone (AEZ)

• **Phase 2: before and during « the South »**
  – mainly Wide Swath SAR acquisitions + Altimetry & Banquis
  ➔ To adjust the gates the safety area of the race just before the passage of the leader

• **Phase 3: hot spots and latecomers**
  – additional Wide Swath SAR acquisitions + Altimetry & Banquis
  ➔ To maintain equity between skippers in terms of safety during the race.
  ➔ To program specific acquisitions on particular cases which require more reactivity

• **+ during all phases:**
  - Analysis and interpretation with Metocean Data (Sea Surface Temperature, current, Wind) and other ancillary data/observations
Tabular Icebergs (Sept 1st 2016)

2 to 3 large tabular icebergs may interfere with VG16:

- A56 (21x12 km)
- B15K (29x5 km)
- B34 (still fasten within in sea ice)

A56 pics from ISS Tim Peak 27 March 2016 (Left) and 2 June 2016 (Right)
Mission Principia ©Peake/ISS/Nasa/Esa
Drifting speed 0.1-0.5 knots.

«captured» by ocean eddies.

Generating tens of small icebergs every day although still in cold water.

Expected to «explode» in the following weeks.

A56 is equivalent to 100,000 ice cubes. (100x100x100m)
Large Tabular A56 Iceberg (as of Mid-Nov. 2016)

Sentinel-1 – 14/11/2016 1949 UTC

40km
Proposal for the 1st version of AEZ

• July + August

• 7 satellites

• No area with high density of icebergs (except East of A56)

• Some isolated icebergs in all the oceans.

• Situation to be updated with 1 additional satellite and longer time series + SAR imagery
Evolution of the AEZ during the race

- AEZ is carefully and progressively refined during the race.
- Huge impact on race as sailboats tend to navigate as close as possible (shortest circumpolar distance) depending upon sailing condition.
SAR images acquisition scenario in 2016/2017

**SENTINEL-1**
<200 S1A/S1B images acquired
- on a pre-defined scenario
- Leg by leg
- Ahead of the leader
- HH-pol

**Radarsat-2**
<50 Radarsat-2 images acquired
- In a reactive manner
- Mostly during the race
- To monitor the situation over the second half of the ranking
About 700 detected icebergs in 2016/2017 in the Atlantic Ocean.
On the use of AIS information

French Territories  21/11/2017
Wave Mode analysis for new source of information

- Higher spatial resolution
  - finer sensitivity to the shape of icebergs
  - CFAR detectors must be adapted

- Both bright and dark signatures are observed
  - Double vs single bounce scattering mechanisms

- Wave modes @23° (WV1)
  - lower double bounces phenomena due to vertical structures
  - Higher backscattered signal from the sea
  - CFAR detector tuned for black echoes gives better results

- Waves modes @36° (WV2)
  - Higher occurrence of double bounces phenomena
  - Lower backscattered signal from the sea
  - CFAR detector for bright targets performs better

- CFAR approach needs prior target’s size -> both small and large icebergs!
Wave Mode analysis for new source of information

- Accumulation of Icebergs detections a few months before the start of the race
  - → to obtain a synoptic view of the statistical distribution
  - Fully automated detectors using an adapted CFAR approach (bright and dark echoes)
  - Classification of detected targets based on:
    - Time-Frequency analysis from SLC data to remove ghosts (transient events)
    - Image segmentation to remove more diffuse targets such as rain cells (ongoing work)

- Ongoing work to assess global and seasonal iceberg locations with WM (from ENVISAT to S1)
Conclusions

• Sustained efforts are needed to combine as many source of information as possible for an optimum use of EO satellite resource, in particular SAR imagery

• Two complementary techniques based on radar
  – SAR imagery and altimeter
  – Sentinel-1 as a cornerstone for “regular” iceberg monitoring service for the first competitors
  – Radarsat-2 used for its more reactive programming properties to refine the iceberg situation over the second half of the rankings

• Analysis, Validation and Interpretation using Meteocean data and ancillary data sources
  – In situ observations
  – Sea temperature, wind, current
  – Suspicious satellite iceberg detections compared to SAT-AIS (confidence index of the detection)

• 2016: New activities with Wave mode compared to VG2012
  – The integration of these products must be improved in the future in terms of algorithms (detection schemes) and processing strategy (huge amount of data to process)

• Rendez-vous for the next yacht races (Brest Ultim 2019, and Vendée Globe 2020)
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